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ABSTRACT

This paper examines how students' reading and mathematics achievement gains over the high school years are influenced by the size of the high school they attend. Analyses of three waves of data from the National Educational Longitudinal Study of 1988 used hierarchical linear modeling methods to examine three questions: (1) which size high school is most effective for students' learning; (2) which size is most equitable; and (3) whether the effects of school size are consistent across high schools defined by their social compositions. Results indicate that the ideal high school, defined in terms of effectiveness (learning), enrolls 600-900 students. Students learn less in schools smaller than this, but students in very large high schools (over 2,100 students) learn considerably less. Learning is more equitable, however, in very small high schools, with equity defined by the relationship between learning and student socioeconomic status (SES). Important for educational policy is the finding that the influence of school size on learning is different in schools that vary by student SES and in schools with differing proportions of minorities. Enrollment size has a stronger effect on learning in schools with lower-SES students, and also in schools with high concentrations of minority students. Implications for educational policy are discussed. Contains 38 references and 11 figures and data tables. (Author/SV)

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High School Size: Which Works Best, and for Whom?

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High School Size: Which Works Best, and for Whom?

Abstract

This study extends earlier work about the effects of high school restructuring on student learning. Although the focus of studies in that research stream was on school reforms located within (or consistent with) the school restructuring movement, the studies included a control for enrollment size as a structural feature of schools. Across the studies, students in smaller schools were shown to learn more, and learning was more equitably distributed by family social class (SES) in smaller schools. School size was not the primary focus of that work; here it is.

Our analyses used three waves of data from NELS:88 and hierarchical linear modeling (HLM) methods to examine how students' achievement gains in two subjects over the high-school years (reading and mathematics) are influenced by the size of the high school they attend. Three research questions underlay our study: (1) "Which size high school is *most effective* for students' learning?"; "Which size is *most equitable*?"; and (3) "Are the effects of school size *consistent across high schools* defined by their social compositions?"

We found that the ideal high school, defined in terms of effectiveness (i.e., learning), enrolls between 600 to 900 students. Students learn less in schools smaller than this; those in large high schools (especially those over 2,100) learn considerably less. Learning is more equitable, however, in very small high schools, with equity defined by the relationship between learning and student SES. Important for education policy is our finding that the influence of school size on learning is *different* in schools that enroll students of varying socioeconomic status (SES) and in schools with differing proportions of minorities. Enrollment size has a stronger effect on learning in schools with lower-SES students, and also in schools with high concentrations of minority students. Implications for educational policy are discussed.

High School Size: Which Works Best, and For Whom?

Introduction

Why Study High School Size?

Three questions. This study builds on and extends existing empirical and synthesis work. Although one strand of that work was intended to investigate the effects of school reforms (particularly school restructuring) on student learning, results from studies in that strand also provide strong evidence that students learn more in smaller high schools, and that learning is also more equitable in smaller school settings (Bryk, Lee, & Holland, 1993; Lee, Bryk, & Smith, 1993; Lee & Smith, 1993, 1995, 1996; Lee, Smith, & Croninger, 1995). But exactly how small should high schools be? There would seem to be a point of diminishing returns, where reducing size could constrain the courses that are offered, and the subject-matter expertise among teachers, to the point where learning is diminished. Although findings about school size from studies of school restructuring have relevance to educational policy, in that they show that most existing high schools are too large to maximize their students' educational progress, they lack the specificity of a more practical question: "Exactly what size works best?"

Beyond "ideal size," two other questions motivate this study. Both target the issue of the equity in student learning. A second question asks, "Does an ideal school size, defined in terms of average learning, also apply to its the distribution of learning across students' social characteristics within the same school?" A third question focuses on the social composition of schools: "Does one size fit all?" We seek answers to these questions with data from three waves of data from the National Educational Longitudinal Study of 1988 [NELS:88]. With nested data and questions that focus on school effects, we employ the methodology most appropriate to these conditions: Hierarchical Linear Models [HLM].

Two criteria for evaluating school size. An enduring issue for educational policy is the optimal size of a school. "Optimal" is defined using two potentially conflicting criteria: (1) how organizational size affects *group members* [a sociological criterion], and (2) the best school size for optimum *economic efficiency*, in that the large majority of schools are financed with public funds [an economic criterion]. At least since the end

of World War II, this topic has been hotly debated in policy circles. Most discussions, located typically within the school consolidation movement, have focused more on economic than the sociological criteria and have a decidedly bureaucratic bent. Although elementary schools are often small, based on an interest in providing intimate relations and a supportive environment, high schools are seen as needing to be much larger in order to accomplish their purpose. The number of students in a school can either facilitate or constrain contact among members (teachers and students), affecting important relationships in both academic and social domains.

Existing work on which this study builds. Our direct interest and familiarity with this issue emerged from a series of studies sponsored by the Center on the Organization and Restructuring of Schools (CORS) at the University of Wisconsin. These studies, using the NELS database to evaluate the effects of restructuring on student outcomes, focused on outcomes of two types: (1) learning (defined as gains in achievement over the high school years) and (2) the social distribution of learning (defined by how learning is associated with students from families with varying social class backgrounds). These outcomes are, of course, related. Although the studies' major focus was on elements of school restructuring defined by CORS' mission (e.g., the organization of the curriculum, the character of instruction, the professional lives of teachers), the studies also took account of other structural and compositional features of schools that might provide alternative explanations for the results on restructuring (e.g., average SES, minority concentration, sector, and size).

At the outset school size was introduced into the analytic models for the purpose of statistical control. However, the consistency of the residual effects of school size on student outcomes was striking. Because the analyses also included variables that are known to be related to school size (such as sector, minority concentration, and other characteristics of school social organization), direct size effects persisted. Over the course of the five-year life of CORS, the findings on size came to be seen as important in their own right: both effectiveness (i.e., learning) and equity (i.e., social distribution) were shown to be higher in small schools. As school size was not an explicit school feature of the CORS center, this issue was not pursued further in that venue.

Within the format of those studies, size was investigated as a linear effect for statistical reasons. As the school size variable is strongly and

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positively skewed (with a large number of small schools), it was subjected to a natural logarithmic transformation. This was to allow use of the measure properly in analyses that made stringent assumptions about the normality of distributions for continuous variables. Consistently significant negative coefficients for the "log-size variable" on student learning allowed interpretation of the findings as, "Smaller is better." However, the true relationship probably was *not* linear. It seemed reasonable that there should be should be an "ideal" high school size where both effectiveness and equity were maximized.

Research Background

Arguments Underlying Research on School Size

Two research strands. Research on size, a standard organizational or structural feature of educational institutions, falls into two categories. Most has targeted high schools. The first research stream reflects an economies of scale argument, and focuses on the potential for increased savings through reduced redundancy and increased resource strength as schools get bigger. The second strand directs attention toward how size influences other organizational properties of schools. As schools grow, it is natural that they become more formal and bureaucratic. Certain consequences flow from such changes, including the degree of specialization of the instructional program. Conclusions from these two streams go in opposite directions: the efficiency argument suggests benefits from incresing size, whereas the organizational argument favors smaller schools.

Economy of scale. This argument, which examines the cost efficiency for "producing" a given level of achievement in students, leads to conclusions favoring school consolidation and larger size (Kenny, 1982). The logic is that savings should accrue as core costs are spread over a larger pupil base. Those savings could be applied toward strengthening (i.e., expanding) the school's academic offerings in response to individual differences among students in interest and ability. This should result in either a general increase in resource strength, greater program specialization, or both. Program specialization is seen as an advantage within this research.

Although this argument assumes that greater size results in an economically more efficient operation (Guthrie, 1979; Michelson, 1972), savings projected by proponents of school consolidation have not materialized

(Chambers, 1981; Fox, 1981). Large schools usually expand their support and administrative staffs to handle the greater bureaucratic demands. In rural areas (where consolidation is a big issue), higher costs for distributing materials and transporting students offset any savings (Chambers, 1981).

Empirical evidence that size and academic outcomes are positively related is weak, though Bidwell and Kasarda (1975) offer some evidence of an indirect relationship. They showed that the availability of resources was positively but indirectly related to achievement. The effect was mediated through hiring better-trained teachers and more staff to support students' special needs. School size and district size are often confused, particularly for high schools (as many districts operate a single high school). The relationship between school *district* size and resource availability is inconsistent across communities, contingent on the socio-economic status of the community (Friedkin & Neccochea, 1988). Although larger districts in low-income areas typically have access to more resources than small districts, the higher incidence of "exceptional problems" in such populations introduces constraints in such schools that contribute to lower achievement.

Academic and social organization. Recent research documents a relationship between organizational size and program specialization. In principle, larger schools have more students with similar needs, and thus would be better able to create specialized programs to address those needs. In contrast, small schools must focus resources on core programs, with marginal students (at either end of a distribution of ability or interest) either excluded from programs or absorbed into programs that may not meet their needs as well (Monk, 1987; Monk & Haller, 1993). However, research on tracking suggests that the extensive differentiation in curricular offerings and students' academic experiences has debilitating consequences (Gamoran, 1989; Oakes, 1985). Increasing size promotes curriculum specialization, resulting in differentiation of students' academic experiences and socially stratification of student outcomes (Lee & Bryk, 1989).

Is increased specialization good or bad? Although this trend clearly fits the bureaucratic view of schooling, where schools are meant to cater to individual differences among students, an alternate perspective -- communal school organization -- sees specialization in another light. The communal perspective has motivated some recent and relevant empirical work on curriculum effects. This work links differences in students' academic

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experiences to social stratification in academic outcomes (Garet & DeLaney, 1988; Lee & Bryk, 1988, 1989; Lee & Smith, 1993). Private and public schools alter their curriculum offerings differently as they increase in size. Although Catholic schools add more academic courses as they grow bigger, public schools typically add more courses in personal development and other non-academic areas (Bryk, Lee, & Holland, 1993).

Basic sociological theory suggests that as an organization grows, human interactions and ties become more formal (Weber, 1947). Organizational growth typically generates new bureaucratic structures, as connections between individuals becomes less personal. These bureaucratic structures, in turn, inhibit communal school organization (Bryk & Driscoll, 1988). This hypothesis has been largely substantiated in the research studies that identify the communal characteristics of effective schools. In much of the literature on school climate, for example, size operates as an "ecological" feature of a school's social structure, part of the physical or material environment that influences the nature of social interactions (Barker & Gump, 1964; Bryk & Driscoll, 1988; Morocco, 1978).

This strand of work concludes that smaller school size is beneficial for students in several ways. The more constrained curriculum in small high schools is typically composed of academic courses, with the result that virtually all students follow the same course of study, regardless of their interests, abilities, or social background. This results in both higher average achievement and achievement that is more equitably distributed (Lee & Bryk, 1988, 1989). Social relations are also more positive in smaller schools. The preponderance of recent sociological evidence suggests that "smaller is better" (Bryk, Lee, & Smith, 1993).

Study objectives. Within any high school, there are clear tensions relating to the number and types of students it serves. Obviously, high schools need to provide some variety in curriculum options, based on the interests, competencies, and future plans of their students. More students increase any particular school's ability to provide those options, in that more students translate into more resources (e.g., the ability to hire teachers with expertise in different subjects, numbers of students to fill optional courses at both end of the academic curriculum). On the other hand, a felt need is that constraining unit size helps to promote the human dimensions of schooling.

We intend our work to build on research that has touched or embraced the issue of high school size. Although most studies have couched the issue within a "bigger vs. smaller" mode, our objective here is to expand that argument, by estimating where an appropriate *balance point* might be. We identify this balance point by examining student learning as a function of school size, although we recognize that size might influence other outcomes differently. The first of our three objectives is to identify that ideal high school size, defined in terms of student learning. A second objective is to define the optimal size in terms of the equitable distribution of learning within schools. A third objective is to identify whether this ideal size is constant across different types of high schools, defined in terms of the types of students they serve.

Data and Method

Data

Sample. We use the first three waves of data from NELS:88, collected on the same students as 8th, 10th, and 12th graders. Besides survey data from students, their parents, their teachers, and their schools, NELS students also completed cognitive tests at each wave. We believe that NELS represents almost ideal data to pursue this study, as school size effects may be estimated on achievement gains between the beginning and end of high school for large random samples of students and schools. As we focus on students during their high-school years, our sample includes those with data at the three waves who also stay in the same high school until graduation: 9,912 students in the 789 public, Catholic, and elite private high schools with sufficient data for the analysis methods we use. Details about filters for selecting this sample are described more fully by Lee and Smith (1995).

Because the NELS sampling design selected schools and students at the base year, when students where 8th graders in middle-grade schools, the design did not involve sampling high schools. The original sampling plan oversampled certain types of schools (private schools and those with high enrollments of Asians and Hispanics); thus, analyses require the use of design weights to compensate for this. Although the National Center for Education Statistics (NCES) supplied student- and school-level design weights at the base year, at the first followup they supplied only weights for students. Because our analyses focus on school effects, it is important

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that the analyses include adjustment with school weights. A major value of NELS data is its representativeness, an advantage on which we wished to capitalize. We solved the problem by constructing our own design weights.[1]

Measures. The major dependent measures in this study are learning in two subjects: mathematics and reading. Learning is measured as change (or gain) in achievement in each subject between 8th and 12th grade. Other work with NELS (Lee, Smith, & Croninger, 1995) has shown that students gain more in the first two than the last two years of high school, so the majority of their "learning" (as measured by the NELS tests) actually occurred early in high school. We chose these subjects because they are (a) very important to students' future success, (b) very different from one another, and (c) they may be differentially amenable to school effects. We limited the subjects to simplify our study; NELS also includes test data in science and history.

The independent variable of special focus is, of course, school enrollment size.[2] Although earlier work used this measure in a form that had been logarithmic transformed, here we used the school enrollment size without transformation. In a preliminary sensitivity analysis, we used the measure, which is highly skewed in a negative direction, in its continuous form. In most analyses, we broke high school size into 8 categories: 300 students or less, 301-600, 601-900, 901-1,200, 1,201-1,500, 1,501-1,800, 1,801-2,100, and over 2,100 students. These categories were decided upon based on sensitivity analyses (described below). In one analysis, we used two piecewise continuous measures (for smaller and larger schools). Other measures in the models were used as statistical controls. Details of construction of all variables used in the study are provided in Appendix A.

Analytic models. The nested structure of the research questions (all of which estimate the effects of school size on student learning), coupled with the NELS data structure, suggests the need for a hierarchical linear model (HLM) approach (Raudenbush & Bryk, 1992). We use a 2-level HLM structure. In Level 1 (between students within schools) we model growth in achievement (in mathematics and reading) over the four yours of high school as a function of the characteristics of students. Outcomes at this level include both learning (i.e., gains in achievement in math and reading) and its equitable distribution (i.e., the relationship between students' family social class, or SES, and achievement gains). To address all research questions, we use the same Level-1 model, which includes controls for student demographics (SES, race/ethnicity, gender) and ability (general measures of

achievement at 8th grade). Student SES is of special interest, as the SES/learning slope is our indicator of social equity within schools.[3]

HLM models estimating size effects on learning. At Level 2 (between schools), the outcomes are average learning (Question 1) in these two subjects and the SES/learning slopes in each school (Question 2). The Level-2 HLM models evaluate the influence of several characteristics of schools on both learning and its equitable distribution. Besides school size, Level-2 models control for school SES, minority composition, and sector (public, Catholic, independent). Preliminary analyses present group means for all measures included in our models by the school size categories described above.

As results below show, the sensitivity analyses suggested an optimal school size in each subject. In general, smaller schools appeared to be more effective in terms of student learning. But it is also evident that the relationship with learning was non-linear. We converted the continuous size measure into categories of 300 students/group and then dummy-coded them. When analyzing effects of any set of dummy variables, it is necessary to designate an excluded group. We selected the size category of 1,201-1,500 students. Although the choice of a comparison is arbitrary, we chose this category because this is about the size high school that the average U.S. student attends.

Differential size effects. Does "one size fit all"? Similarly, "Does school size influence learning differently in schools of different types?" It seems unlikely that a single optimal size is appropriate for all types of schools and students. Thus, Question 3 explores how school size influences learning in schools with different social compositions. We focused on average school SES and minority concentration. Because the minority composition of high schools is not normally distributed, we created a dichotomous variable whereby schools that enroll 40 percent minority students or more are coded "1", schools with less than 40 percent minority students were coded "0."

We pursued an interaction analysis strategy. For average school SES, we created a set of effect-coded interaction terms with the size categories, and entered them into the full HLM model. Because minority concentration was a dummy variable (making the estimation of a large set of interaction terms particularly difficult), we created two piecewise linear terms, and computed product terms of each with minority concentration.[4]

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Presentation of results. Our analyses included multiple quantitative analyses and a large number of results. Descriptive results are presented in a table of group means on all variables used in the study. Because our focus is on the effects of school size on learning and its equitable distribution, we chose to present our HLM results in graphic form, rather than in tables. All graphs that represent school size effects include statistical adjustment for the entire set of control measures described above, both within-school and between-school controls.

Effects are presented in two different metrics. Those that answer Questions 1 and 2 are presented in an effect-size metric. For Question 3, effects are presented as adjusted group means in average gain-score points on the NELS reading and mathematics tests for each of the eight school-size cateogories. We selected the graphical mode of presentation because it displays "the story" in form understandable to a non-technical audience. For readers interested in the technical details of our analyses and in the magnitude of effects of the control variables, we provide numerical results of the full HLM analysis for each research question in Appendix B. Non-technical readers may skip over these results.

Results

Descriptive and Exploratory Analyses

Characteristics of students and schools by school size. The distribution of size for the high schools in our NELS sample is positively skewed with a median size of about 1,200. Although there are quite a few small *schools* in the sample and even more in the population, of course more *students* in the population attend large schools. Table 1 displays unweighted sample sizes and weighted means of the variables included in this study by the eight size groupings. Variables are grouped by whether they describe students or schools (i.e., by Levels 1 and 2 in the HLM models). Because a close to fixed number of students was sampled in each NELS school as part of the original sampling design, both student and school sample sizes are reasonably well distributed across schools of different sizes. There are, however, somewhat more students and schools in the moderate size categories.[5]

In general, learning gains are largest in moderate-sized to small schools, although not in the smallest ones.[6] However, such schools also

enroll somewhat more able and higher-SES students. School factors are more varied by size categories. Average SES is somewhat higher in the moderate-sized schools (600-900 and 1500-1800 students), whereas it is lower in very small and very large high schools (group differences under .2 SD). Minority concentration is highest in larger schools. The large majority of schools in all categories are public; private schools are most numerous in the 600-1200 range (which may explain the higher observed SES and ability means for these groups. Differences in both student and school characteristics by school size, while not large, suggest the importance of taking these differences into account in evaluating size effects on learning.

Insert Table 1 about here

Sensitivity analysis. How, exactly, to model school size effects on learning motivated a set of sensitivity analyses. Decisions about cutoff points for the eight size categories was guided by these analyses. Although the descriptions of demographic and learning differences by size groupings in Table 1 suggest a pattern, we felt it was important to take other student and school characteristics into account, as descriptive differences could actually result from other important school features (especially sector). The multivariate sensitivity analyses used a multilevel residual technique. We ran an HLM model similar to what we described earlier (but without school size) on each learning and equity outcome (average learning in math and reading) and saved the residuals from the analysis. We plotted these residuals against the linear version of the school size measure. Figure 1 displays the scatterplot for residualized mathematics learning (MTHRES) against school size (ENRLHS).[7]

Insert Figure 1 about here

The scatterplot in Figure 1 indicates that residual mathematics learning varies by school size, and that the relationship is non-linear. An optimal size range is suggested. Reflecting the distribution of learning gains by school size shown in Table 1, schools whose enrollments range between 500 and 1,000 students appear to be favored in mathematics learning. In schools smaller than that, learning appears to drop. More dramatically, learning is lowest in the largest schools.

Multivariate Models: Which Size High School Works Best?

Effects on learning in mathematics and reading. Results of analyses assessing the effects of high school size on achievement gains in mathematics and reading over the course of high school, are displayed in Figure 2. Effects, presented in an effect-size (SD) metric,[8] were estimated in a two-level HLM model that includes adjustment for the characteristics of students and schools listed in Table 1. We interpret effect sizes (ES) as large if .5 SD or more, moderate if .3-.5 SD, small in the .1-.3 SD range, and trivial if less than .1 SD (Rosenthal & Rosnow, 1984). Because the contrasts are somewhat arbitrary, we do not focus on statistical significance. Our discussion focuses, rather on the relative magnitudes of school size effects displayed in Figure 2.

Insert Figure 2 about here

Size effects are larger for learning in mathematics (darker bars) than in reading (lighter bars), though the pattern is similar for both subjects. All effects are compared to the 1,201-1,500 size category which, by that definition, has no effect. Our analyses indicate clearly that students who attend high schools that enroll between 600 and 900 have optimal learning. Gains are less in smaller schools (particularly those with less than 300 students); learning is also considerably less in large schools (with more than 2,100 students). Effect sizes are very large for mathematics learning (over 1 SD in several cases); moderate effects accrue for gains in reading comprehension.

Effects on the equitable distribution of learning. The school size effects on the relationship between SES and learning in mathematics and reading were estimated simultaneously in the same HLM model as the learning effects shown in Figure 2. We display these effects separately (Figure 3) however, because their interpretation is somewhat different. In virtually all schools, the relationship between SES and achievement or learning is positive -- higher-SES students learn more. Thus, by definition school size effects that are negative are more equitable, as they *decrease* the relationship between SES and learning. In general, size effects on equity are considerably larger than those on learning (many over .1 SD). Although size effects on learning are larger for mathematics than reading, size effects on equity are generally more substantial for reading.

Insert Figure 3 about here

The pattern here is also clear: learning is distributed more equitably in smaller schools. The pattern of school size effects on the SES/gain slopes is generally linear, rather than exhibiting any special advantage of high schools of moderate size. In reading, the equity advantage is largest in schools with 300-600 students (ES of about -3 SD); in mathematics, the largest equity advantage occurs in the smallest high schools (ES aroung -1 SD). As with size effects on achievement gains, learning is distributed least equitably in the largest schools (especially in reading). Readers interested in effects of each variable in the full HLM models (and in nominal significance levels), may consult Appendix B-2 for the numerical results for the full Level-2 HLM models on mathematics and reading gains and slopes shown in Figures 2 and 3.[9]

Multivariate Models: Which Size High School Works Best For Whom?

Size effects in low- and high-SES schools. With HLM we also estimated whether school size effects are constant across schools with different social compositions. Our first analyses investigate how school size effects on learning vary by the social class composition of a high school. We approached this task by creating an interaction term for each school-size category with school average SES, and included these in the HLM analyses on learning in each subject. Rather than presenting the results here in effect-size units, we display adjusted gains for schools in each size and school SES category. We designated low-SES schools as those whose average school SES is one SD *below* the sample average for school SES. Similarly, high-SES schools are those with an average school SES one SD *above* the sample mean.[10] We display the results of these analyses for students' gains in mathematics achievement in Figure 4. Although we conducted an identical analysis for achievement gains in reading, the interaction effects were not statistically significant for that outcome. Thus, we focus our discussion on patterns identified for learning in mathematics.

Insert Figure 4 about here

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Three findings may be drawn from Figure 4. The first is unsurprising, although noteworthy and troubling. Students learn considerably more mathematics in higher-SES schools (gray bars) than in lower-SES schools. Recall that these differences in learning are computed with statistical adjustment for several other social characteristics of students and their schools are taken into account. The second finding is more surprising. The optimal school size is quite similar in both low- and high-SES schools. That is, schools in the 600-900 enrollment range have the highest achievement gains in both groups. Students who attend schools that are either larger or smaller than this optimal size don't learn as much mathematics.

The third finding is the most striking and the most important. School size appears to *matter more* in schools that enroll less advantaged students. Although learning differences are notable for low- and high-SES schools of 600-900 students (about 2 points of gain on a 40-point test), in schools with less than 300 students, this difference is larger (about 3.5 points). In the largest schools, the differences in learning are striking (about 5 points). We also know from Table 1 that the average school SES in very large and very small high schools is low (-.32 SD in the largest schools, -.21 SD in the smallest schools). Our findings suggest that large numbers of socially disadvantaged students attend high schools of a size where, in fact, students like them appear to learn the least.

Size effects in schools with high and low minority enrollments. We also explored whether school size effects were constant across schools with student bodies of high and low minority concentration. The distribution of the proportion of minority (Black and Hispanic) students in U.S. high schools is decidedly non-normal. Large proportions of high schools enroll very few minority students; smaller proportions of high schools enroll mostly minority students. Because of these distributional difficulties (that reflect a substantively important pattern of school segregation that has persisted for many decades), we created a dummy-coded variable to tap minority concentration (see Appendix A). Schools with fewer than 40 percent minority students are contrasted with those enrolling more than 40 percent.

Because of this coding, the interaction terms in this analysis are somewhat different. Two linear piecewise variables captured large and small sized schools (see Appendix A for exact codings). We computed product terms of these variables with an effect-coded form of the minority concentration

dummy variable. Using the size codings in the piecewise terms, we calculated average gains for schools in each size category for schools with low- and high minority concentrations. The results of the HLM analysis for gains in mathematics are displayed in Figure 5; results for reading gains are presented in Figure 6. In both subject areas, the interaction terms between school minority concentration and school size were statistically significant.

Mathematics. The differentiation of learning gains in mathematics, in schools with low minority enrollment (gray bars) and high minority enrollment (black bars), is less striking than the contrasts by average school SES shown in Figure 4. Again unsurprising (but troubling) is the finding that mathematics learning is generally lower in schools with more minority students. As we saw for school SES, the optimal size for schools with differing minority concentrations is the same, although with these analyses the peak is for schools in the 900-1200 range.[11] Very small schools with high minority enrollments seem to show slightly higher gains. We know from Table 1 results that very small schools enroll fewer minority students. As we saw in Figures 3 and 4, the most socially differentiating environments are large. Very large schools with high minority enrollments have quite low learning gains and differences are greatest. It is clear from the analyses in this paper that large schools are quite problematic environments for learning, especially for those that enroll high proportions of minority students. Numerical results from which the values in Figure 5 (mathematics) are displayed in Appendix B-4.

Insert Figures 5 and 6 about here

Reading comprehension. Although our analyses discovered no interactions for school size and average school SES on learning in reading, such interactions were statistically significant with school minority concentration (see Figure 6). In general, the patterns are the same on the two outcomes. For schools with both low and high concentrations of minority students, students in schools in the 600-1200 size ranges learn most in reading. There are especially large learning differences in the largest schools. Especially for high-minority schools enrolling over 1,800 students, on average students gain little in reading comprehension over the course of high school. In the very largest schools, regardless of minority

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concentration, students gain almost nothing. The actual magnitudes of the gains are lower in reading than in mathematics; this is surely an artifact of the relative length of the two tests (21 items on the reading test; 40 items on the mathematics test).

Discussion

Summary of the Effects of School Size

We summarize the findings from this study with four general conclusions about the optimal size of high schools. "Optimal" is defined in terms of students' learning over the course of high school in reading comprehension and mathematics. The discussion is organized as follows. First we present the conclusions that flow from this study. This is followed by a summary of recommendations about high school size in some important writings. We close with a discussion of some issues underlying the relationship between high school size and student learning. In our opinion, conclusions 2 and 4 warrant special attention.

Conclusion 1: High schools should be smaller than they are. The results displayed in Figures 2 and 3 take into account many demographic characteristics of students and structural characteristics of schools other than school size. The analyses provide strong evidence to support the learning advantage of attending small high schools. Although size effects are not identical for learning in the two subject areas considered here, and although they differ somewhat for *effectiveness* (i.e., learning levels) and *equity* (i.e., the distribution of learning by student SES), we feel confident in concluding that high schools should be considerably smaller than they are if the nation wishes to maximize achievement. Students learn more in smaller high schools; learning is more equitable in small places.

Conclusion 2: High schools can be *too* small. Quite honestly, a major motivation for this study was to investigate current policy claims that smaller high schools are better. As mentioned at the outset, it seems logical that high schools could be *too* small to offer adequate academic programs to their students (unless their resource levels were very high and their client base quite homogeneous). Our results confirm that. Very small high schools, as well as very large ones, are also problematic, in that students learn less in high schools with fewer than 600 students, although learning is quite equitably distributed in very small schools. In general

terms, our results lead us to recommend an enrollment size of between 600 and 900 students as "ideal" for a high school.

Conclusion 3: Ideal size does not vary by the types of students who attend. Some of our analyses investigated whether our recommendation about an ideal size should be generalized to schools defined by differing social characteristics. This issue is important, since there is a tendency for socially disadvantaged students to be educated in very large or very small schools. Our investigations examined whether either smaller or larger high schools would be more advantageous for schools that enrolled different types of students. We focused on schools differentiated by their social class and minority concentrations. The same pattern of results was evident: schools whose sizes fall in the moderate size range (600-900 students) were favored for low- and high-SES high schools and for schools with low and high-minority concentrations. Thus, our recommendation for the ideal size of a high school stated in Conclusion 2 holds across high schools regardless of the average social backgrounds of their students.

Conclusion 4: School size is more important in some types of schools. Hopefully, at a minimum we have convinced readers that high school size is an important determinant of learning for *all* students. However, size seems to matter more for some students than others. Our findings indicate that size is especially important for the most disadvantaged students. That is, student learning for these students falls off sharply as the schools they attend become larger or smaller than the ideal. We consider these findings very important, because minority students are particularly likely to attend large schools, and students of lower social class are likely to be found in either large or very small schools (Table 1 shows this). We argue that this conclusion about school size is especially important if we wish to increase social equity in educational outcomes in America's secondary schools.

Popular Writings About School Size

The issue of high school size has received much attention in theoretical and popular writings about education, as well as reports spelling out ideas for reforming schools. The empirical research on the topic is, however, neither numerous nor strong. Although we reviewed relevant empirical work in the background section of this paper, reflecting on our results led us back to other relevant writings. We were gratified that our conclusions

about the ideal size of a high school are in line with recommendations about high school size made by other scholars, although the latter were not drawn directly from empirical analyses. One example is James Bryant Conant, acknowledged as the father of the comprehensive high school. In his influential 1959 book about the American high school, he indicated that a school with a graduating class of 100 should be sufficiently large to implement his recommended curriculum. Quite obviously, contemporary comprehensive high schools are considerably larger than this.

John Goodlad has written more recently about school size. In his thoughtful book about school reform, A Place Called School, he stated: "The burden of proof, it appears to me, is on large size. Indeed, I would not want to face the challenge of justifying a senior... high of more than 500 to 600 students (unless I were willing to place arguments for a strong football team ahead of arguments for a good school, which I am not)" (Goodlad, 1984, p.310). Bryk, Lee, and Holland (1993) presented empirical evidence that school size has more influence on social equity than on achievement in Catholic and public high schools, although they made no specific size recommendation. They concluded: "Quite simply, it is easier to create a more internally differentiated academic structure in a larger school" (Bryk, et al., 1993, p.270). Though the Coalition for Essential Schools has also made no specific recommendations about high school size, Coalition founder Theodore Sizer, in Horace's Compromise, included "keep[ing] the structure simple and flexible" among the five "imperatives for better schools" (1984, p.214).

Over the last few years, the Carnegie Foundation has thrown its weight behind two very influential reports on school reform. Their 1989 report, Turning Points, focused on policies for changing middle-grade schools. Their first recommendation was to "create small communities for learning" (Carnegie Council on Adolescent Development, 1989, p.9). Although the report made no explicit recommendations for the ideal size for a middle school, the it listed key elements of such communities as "schools-within-schools or houses" (p.9). The Carnegie Foundation's most recent policy statement on school reform has focused on high schools, and is entitled Breaking Ranks. The report represents a joint effort with the National Association of Secondary School Principals (NASSP, 1996). Using the word "personalization" -- terminology identical to a major element in the Coalition for Essential Schools -- the first of the report's six major

themes recommended that, "[h]igh schools must break into units of no more than 600 students so that teachers and students can get to know each other" (NAASP, 1996, p.5).

Another recent report spelled out a "radical" school reform effort in one major U.S. city (Philadelphia). The reform in question involved the creation of 90 charter schools within the city's 22 comprehensive high schools (Fine, 1994). Although the schools described in the report were specialized in some sense (as charters typically are), the tenor of the report definitely favors smaller high schools and the communities that are fostered within them. All the charters were created as schools-within-schools. The report summarized how teachers in the charters schools described the effect of *expanding* the size of the charters (from 200 to 400 students) as follows: "[T]he seams of the charters feel too tightly stretched" (p.131). The major worry, however, focused on deterioration in social relationships within and between groups of students and teachers. Learning was not a major focus of the Fine book.

These reports, most of them quite recent, sing a consistent song: high schools should be smaller than they are. This theme is supported by our first conclusion. The major theme underlying the suggestion for reducing high-school size is that relationships in smaller schools will be more personalized. We are struck with the consistency of the recommendations for an ideal size (the number 600 seems very popular), although our reading of these books and reports did not uncover any empirical evidence to support that specific recommendation. Although not every educational policy recommendation requires specific evidence to support it (some rest on solid moral ground), we wonder how these writers arrived at such a specific and consistent recommendation.

We were also quite surprised that these writings did not seem to recognize that perhaps a high school could be *too* small. Although our findings do center somewhere around the same magic number as an ideal size, they also suggest that very small high schools might not be advantageous for their students' learning. If personalization were an end in itself, then it is probably the case that "the smaller the better" would hold. However, we believe that it is difficult to overlook that the major aim of schools in general, and high schools in particular, is (and should be) learning. Thus, we wonder why these writers don't worry about very small size.

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Importance of Findings for Policy and Practice

A causal link? Does a reduced school size really "cause" students to learn more? Although our estimation of direct effects of enrollment size on student learning would imply this, we are cautious about drawing a direct causal link between the number of students a high school serves and how much students learn in school. Rather, we suspect that size acts as a facilitating or debilitating factor for other organizational characteristics or practices which, in turn, promote student learning.

At the outset, we described two conflicting theories about school size. One theory focuses on curriculum. Size can be a facilitating factor in offering a more specialized curriculum, which in turn allows schools to differentiate what their students learn to better respond to individual differences. We also mentioned that smaller schools are more likely to offer a core curriculum which all (or most) students may follow, regardless of their abilities or aspirations (responding to common needs rather than individual differences). Our findings here that favor smaller schools (but not *too* small) suggest that there is a balance which might favor enough courses to serve students well, but not too many to foster differentiation.

A second theory focuses on social relations. This theory clearly favors small schools, in that social relations between school members are likely to be more collegial (among teachers, or between teachers and administators) and more personalized (between teachers and students, among all school members). John Goodlad (1984) raised a third policy issue that may be very important among people who work in schools and within the communities the schools serve -- the ability to sustain winning sports teams. Despite its importance to many constituents of U.S. high schools, we are hesitant to raise this concern to the level of theory. However, the extra-curriculum in any high school, and students' participation in it, is an important element in the secondary school experience. And it is surely influenced by school size.

Although our analyses lend strong support for the presence of a direct link between high school size and student learning, the logic argues otherwise. We suggest that our findings about size probably represent a proxy explanation for basic organizational features of high schools -- the character of the curriculum, relationships among school members, and the extra-curriculum. We plan to pursue these issues in future field-based research. The approach to understanding the school size effects we have

shown would suggest that its effect on learning is probably indirect, through its influence on basic features of the academic and social organization of schools. Under this explanation, size is simply a facilitator or inhibitor of these more fundamental characteristics of the social and academic organization of schools. On the other hand, policymakers would probably argue that changing the size of a school is considerably easier than altering its basic organizational features.

Empirical results might really influence public policy. High school size, and its effects on students, is one topic of empirical research that the general public can understand. The fact is that social policy may be out in front of solid empirical support in this instance. A series of front-page articles in the *New York Times* recently (Dillon; Dillon & Berger; Firestone; Gonzalez, May 22-25, 1995) present interesting stories about several of the 46 small and experimental high schools that have opened in New York City over the last two years. The major criterion defining these schools is smallness (in the 110-660 range). Reflecting one of the themes we mentioned -- social relations -- Joseph A. Fernandez, the former New York City Schools Chancellor, decried that "Our high schools were just too large, and there were a lot of problems with kids not feeling people even knew who they are," as he launched the movement in 1994. According to the *Times* articles, 50 more small schools were on the drawing boards in New York, with support for the movement from the $25 million Annenberg Foundation educational grant to New York City. New York and Philadelphia are just two of many cities on the "small school bandwagon."

These developments -- where changes are proceeding without research that supports them -- suggest (a) the importance of the empirical work on this topic and (b) an unusual receptivity among practitioners to research results. They also indicate that a move to small schools may actually result in a number of schools that are really *too* small to be effective for the learning of their students. This is one case where scholars do not have to argue for the importance of research to mobilize school professionals toward reforms. In this case, reform efforts are in full gear.

How do we change school size? Clearly, the New York experiment (with its generous foundation support) represents one way to approach changing the average size of a high school: create brand new schools. Our findings suggest that this approach, opening many very small schools, might not be wise. In fact, the *Times* series reported several problems in these high

schools. Given the present fiscal environment and modest public support for investment (financial or psychic) in social betterment, it seems unlikely that America's public school districts will embark on a new building campaign to create many new smaller high schools. This is especially unlikely in many of the nation's largest high schools, which are located in the middle of our largest cities where financial resources are particularly problematic.

A reasonable approach is a movement to create a set of smaller schools-within-schools inside larger high schools. In fact, this movement is fluorishing at present.[12] This policy seems to us a reasonable approach to breaking up large school units, which our study has shown are especially problematic places for learning. However, we suggest a few cautions that policymakers should consider if they wish to adopt the schools-within-schools approach to reducing unit size. First, it is quite important that the actual size of the resulting units be considered. Our research also indicates that quite small units are problematic. Thus, our conclusions about an "ideal" size should be taken seriously. Second, we believe that it is very important that the school-within-a-school decision *not* be used as a way to create a number of "specialty shops" (Powell, Farrar, & Cohen, 1985) -- by ability, vocational focus, or other orgnizational means to differentiate students and their high-school experiences. Rather, each smaller unit should reflect the demographic diversity of the school as a whole. To do this, it would be appropriate that students and faculty be selected randomly for sub-group membership.

A final clarion call emphasizes the special importance of high school size for economically disadvantaged and minority students. U.S. policy and custom about which students attend which schools is that such decisions are made locally, and usually this means that they are based largely on residential catchment area. Residential segregation in the U.S. is increasing rather than decreasing over time (Farley & Frey, 1994), and de facto school segregation by race and class are common and seemingly acceptable to the American public. It is well known that secondary school students of color, and those who come from low-income families, tend to be concentrated in U.S. public schools with others quite like themselves (at least demographically). Such students are also more likely to be in larger schools. The issue of school size is much more important in schools with high concentrations of low-income and minority students. Thus, schools with many minority

students, and those with many students from lower-SES families (often the same schools), should be especially anxious to reduce the size of the units in which their students actually learn.

Technical Notes

1. More detail on this procedure is available in Appendix A of the Lee and Smith (1995) article or from the authors. The construction method for the school weights included the probabilities of (a) the sector in which students in each school had spent their 8th-grade year, (b) the total enrollment of each high school, and (c) the aggregated student-level weights supplied by NCES.

2. Because the study relies on an accurate measure of school size available only on the restricted NELS data files, we note that the first author holds a current licence from NCES for using NELS restricted data (L-912050011). The second author holds a separate licence through her home university.

3. In HLM parlance, SES is set to be "free" and the other within-school control variables are "fixed" (i.e., the variability of these variables is contrained to zero between schools). As such, SES is grand-mean centered, whereas gender, minority status, and ability are centered around their respective school means on these variables. More detail on HLM centering procedures is provided by Bryk and Raudenbush (1992). We control for initial status, or ability, in these analyses by computing an z-scored average of the students' 8th-grade scores in the three tests besides the subject being assessed (e.g., the ability control for gains in mathematics achievement included base-year test scores in reading, science, and social studies).

4. The two piecewise size terms (representing small and large high schools) were computed as follows. First we computed an average school size for each of the 8 size categories. We used a school size of 900 as the cutpoint for estimating the values for the piecewise terms, as our analyses indicated that 900 was close to optimal. The exact codings for the two piecewise terms are given in Appendix A. Using piecewise terms in HLM models (albeit in a somewhat different context) is spelled out by Bryk and Raudenbush (1992).

5. The sample for this study is the same used in our studies of school restructuring (Lee & Smith, 1995, 1996; Lee, Smith, & Croninger, 1995). Because HLM was used in all these studies, the sample at 10th grade was restricted to high schools with at least 5 NELS students enrolled in them. This selection criterion resulted in droping quite a few small private schools (particularly those with a single NELS student in them. Lee & Smith (1995) provide details of sample selection. Although the sample for this study is, thus, somewhat biased toward larger schools, the number of smaller schools is large enough to support the types of analyses performed here. All students in the sample schools with test scores at 8th and 10th grades were retained. Because students who were dropped from the sample through these filters were somewhat more advantaged than those retained, the bias introduced by the sample selection criteria under- rather than overestimate the effects we observe.

6. Because the constructed school-level weights included school size as one component (see Note 1), we compared the patterns of achievement gains by

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school size in weighted an unweighted analyses. Appendix B-1 displays group mean comparisons for achievement gains (in a z-score metric). The patterns are generally quite similar -- except in the smallest schools, where the unweighted gains are somewhat larger. There is a pattern of somewhat smaller SDs for weighted than unweighted group means.

7. The patterns for residual learning in reading (as well as science and history, the other subjects tested in NELS) were quite similar, so we have not included ther here for the purposes of parsimony.

8. The effect sizes are computed by dividing the gamma coefficients for each dummy-coded school size category on achievement gains (or SES slopes on gains) by the between-school SD in the outcome estimated in a Level-1 HLM model. The HLM-estimated Level-1 SDs are as follows: math gain: 2.276; reading gain: 1.494; SES/math gain slope: 0.950; SES/reading gain slope: 0.347 (see Appendix B-2). This is the same procedure followed in many other published studies using HLM, where effects are typically reported in between-school SD (effect-size) units.

9. Because our school-level weights included high-school enrollment size as one component, we wondered if results would differ if estimated without weights. We computed similar HLM models to those from which the figures in Figures 2 and 3 were computed, and for which full models are displayed in Appendix B-2. The unweighted school size effects are displayed in Appendix B-3. We draw three conclusions by comparing results in Appendices B-2 and B-3: (1) unweighted school size effect estimates are somewhat smaller than weighted estimates; (2) the *pattern* of effects is very similar between weighted and unweighted analyses, even if the *magnitudes* are somewhat different; and (3) the estimated between-school SDs of outcomes from Level-1 analyses are also smaller for the unweighted than the weighted HLMs (also reported in Note 6.

   Which results are right? We argue that school-level case-weighting is necessary because of the NELS sampling design. But we also recognize the inherent difficulties of using weights here. Readers are left to draw their own conclusions.

10. Because each size category was effects-coded (1, -1), the various interaction terms were computed by multiplying each effect-coded categorical variable by school average SES. Along with the size main effect and the same sets of control variables that were included in analyses for Figures 1 and 2, we included the set of 7 interaction terms in Level 2 of the HLM analysis. We then computed means for each school size category by summing the appropriate terms, and substituting either -1 (for low-SES schools) or +1 (for high-SES schools) in these equations.

11. The peak at a slightly different location is probably an artifact of the cutpoint we used for the two piecewise terms -- 900 students. Thus, we concentrate more on the general patterns than the actual peak.

12. In another study that involved linear estimates of school size effects, we suggested that policymakers should consider schools-within-schools as a feasible and cost-effective way to reduce high school size (Lee & Smith, 1995). Because the NELS high school principals were asked to indicate whether they actually had this policy in place in 1990, we

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investigated whether the policy related to the school's size (i.e., whether principals were reporting the size of the smaller unit or the larger one). We found that this option was essentially a public-school phenomenon (almost no private schools had it). Among the 672 public schools in our sample, 86 (or 13%) offered schools-within-schools. Moreover, these were larger high schools (average size of 1,691) compared to those without the option (average size: 1,275). Although the high schools with the schools-within-schools option enrolled somewhat more minority students (34% vs. 24%), other selection criteria (e.g., (average achievement at high school entry, average SES) were very similar in public schools with and without that option.

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Table 1: **Means of Variables Describing Students and Schools for Several Categories of High School Size** (n=9,912 students in 789 schools)

School Size	Below 300	301-600	601-900	901-1200	1201-1500	1501-1800	1801-2100	Over 2100
Student Sample	912	830	1667	1645	1319	1205	1263	971
A . Means of Variables Describing Students								
1. **Outcomes**								
Mathematics Gain	8.91	12.13	15.69	13.44	12.20	11.61	10.18	7.84
Reading Gain	4.54	6.28	7.61	6.46	5.05	4.60	4.34	3.45
2. **Control Variables**								
Ability, Math (a)	.03	.17	.17	.18	.12	.18	.05	.11
Ability, Reading (a)	.05	.21	.14	.19	.13	.21	.07	.15
% Female	52.8	51.5	47.9	49.9	52.7	52.4	52.9	50.4
% Minority	14.5	24.3	14.3	18.0	16.6	15.6	23.5	21.5
Social Class (b)	-.12	.07	.11	.05	.03	.08	-.04	-.06
A. Means of Variables Describing Schools								
School Sample	75	67	148	139	82	70	101	106
Average SES (b)	-.21	.09	.18	.08	.09	.18	-.15	-.32
% High Min'ty (c)	20.3	26.9	16.3	21.2	15.8	14.5	26.1	33.3
% Public	95.0	92.5	75.5	81.2	90.8	89.4	92.8	95.9
% Catholic	2.5	4.5	10.9	12.2	6.6	6.6	0.9	3.1
% Independent	2.5	3.0	13.6	6.6	2.6	4.0	6.3	1.0

a. Students' average achievement at 8th grade in the three other subjects used as a proxy measure of ability, mean [M]=0, SD=1.
b. Variables are z-scored at M=0, SD=1 on this sample.
c. Schools with more than 40% minority students (Black or Hispanic) coded 1, others coded 0, due to non-normal distribution.

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Figure 1: Sensitivity Analysis of School Size Plotted Against Gains in Mathematics Achievement, Adjusted for Other Characteristics of Students and Schools

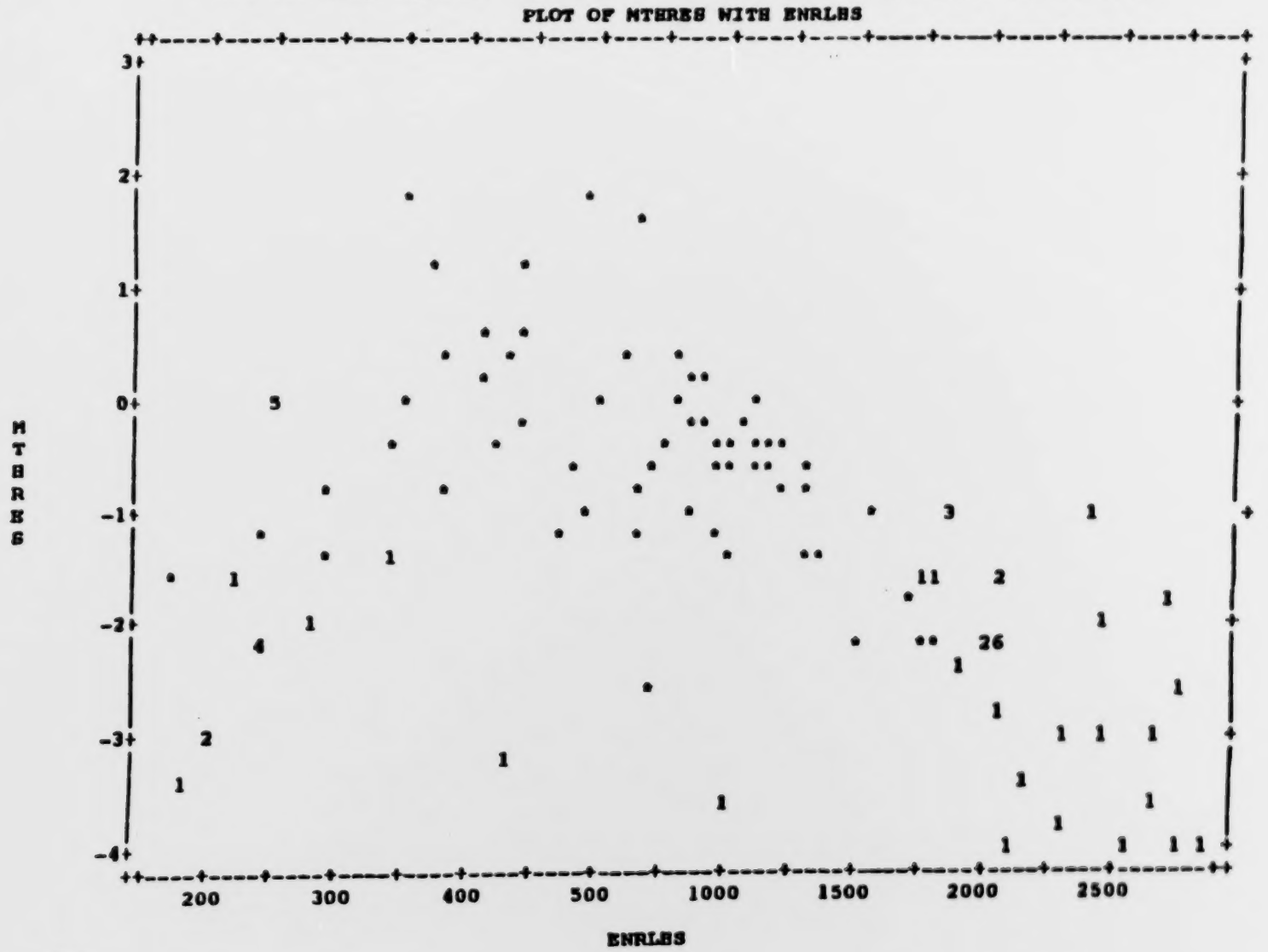

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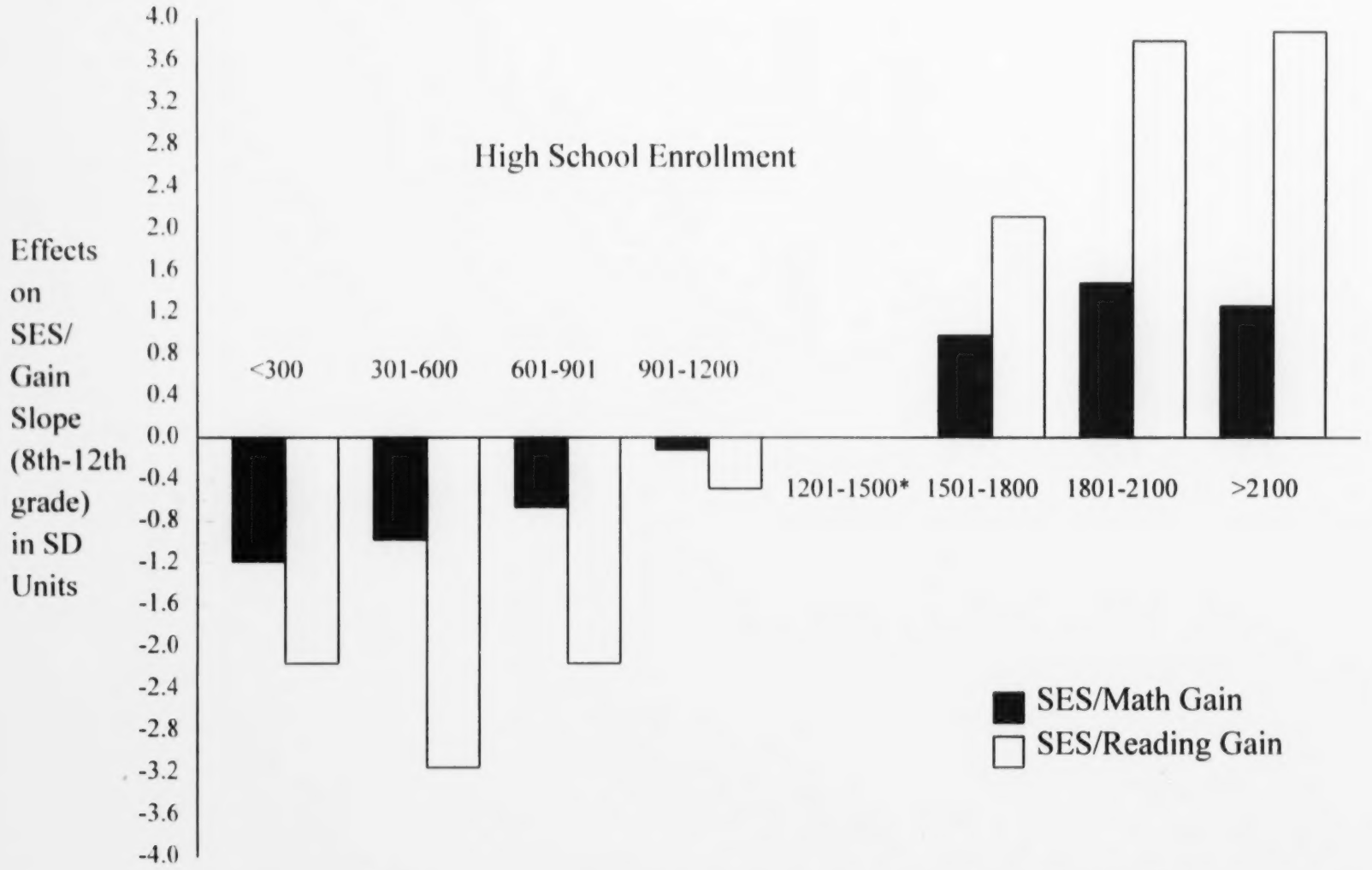
Figure 2: Effects of High School Size on Achievement Gains in Mathematics and Reading

*1201-1500 students was used as the comparison group; thus by definition effect sizes are zero.

Figure 3: Effects of High School Size on the Relationship Between SES and Achievement Gains in Mathematics and Reading



*1201-1500 students was used as the comparison group; thus by definition effect sizes are zero.

Figure 4: Average Gains in Mathematics Achievement by High School Size in Low-SES and High-SES High Schools

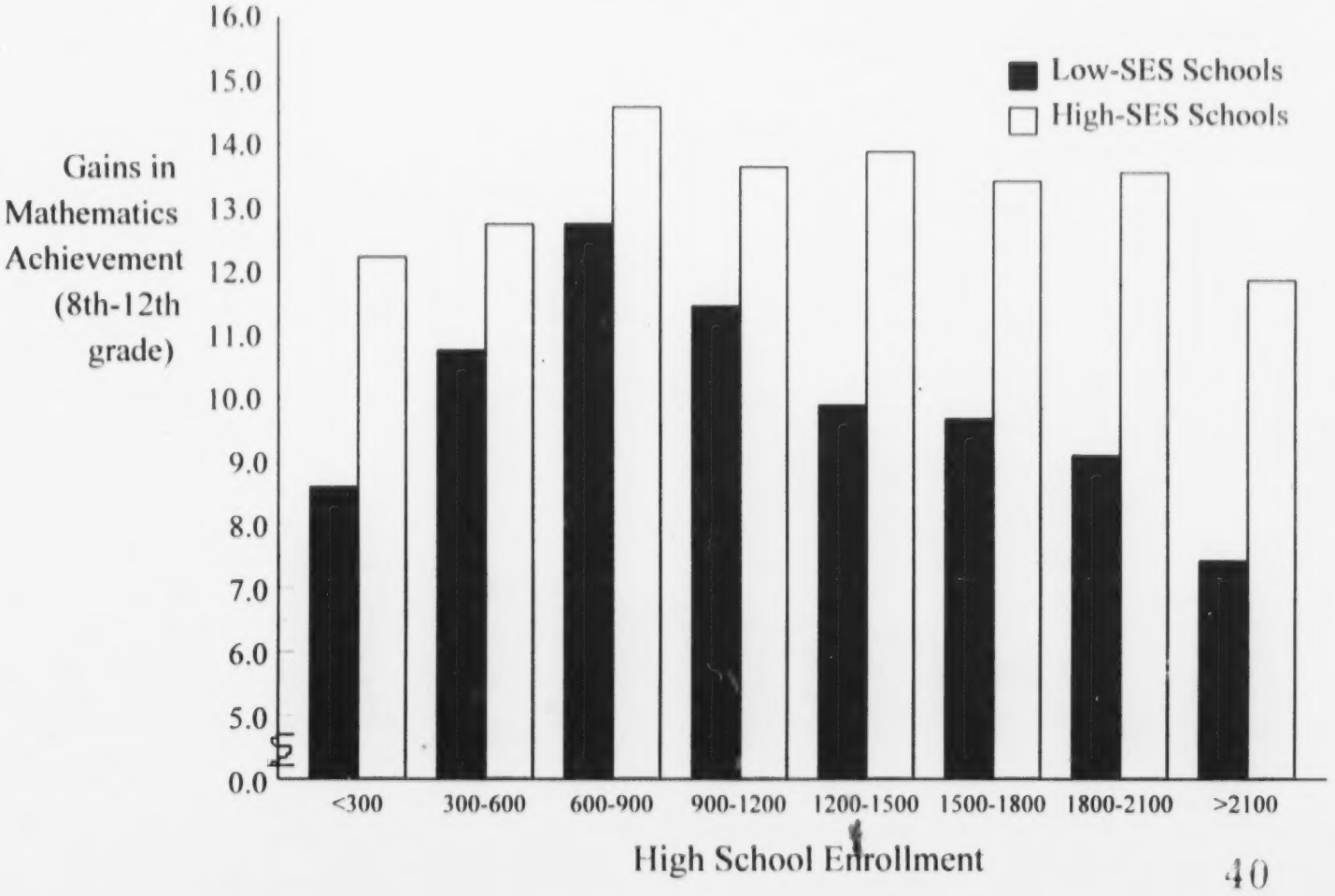


Figure 5: Average Gains in Mathematics Achievement by School Size in High Schools with Low- and High-Minority Enrollments

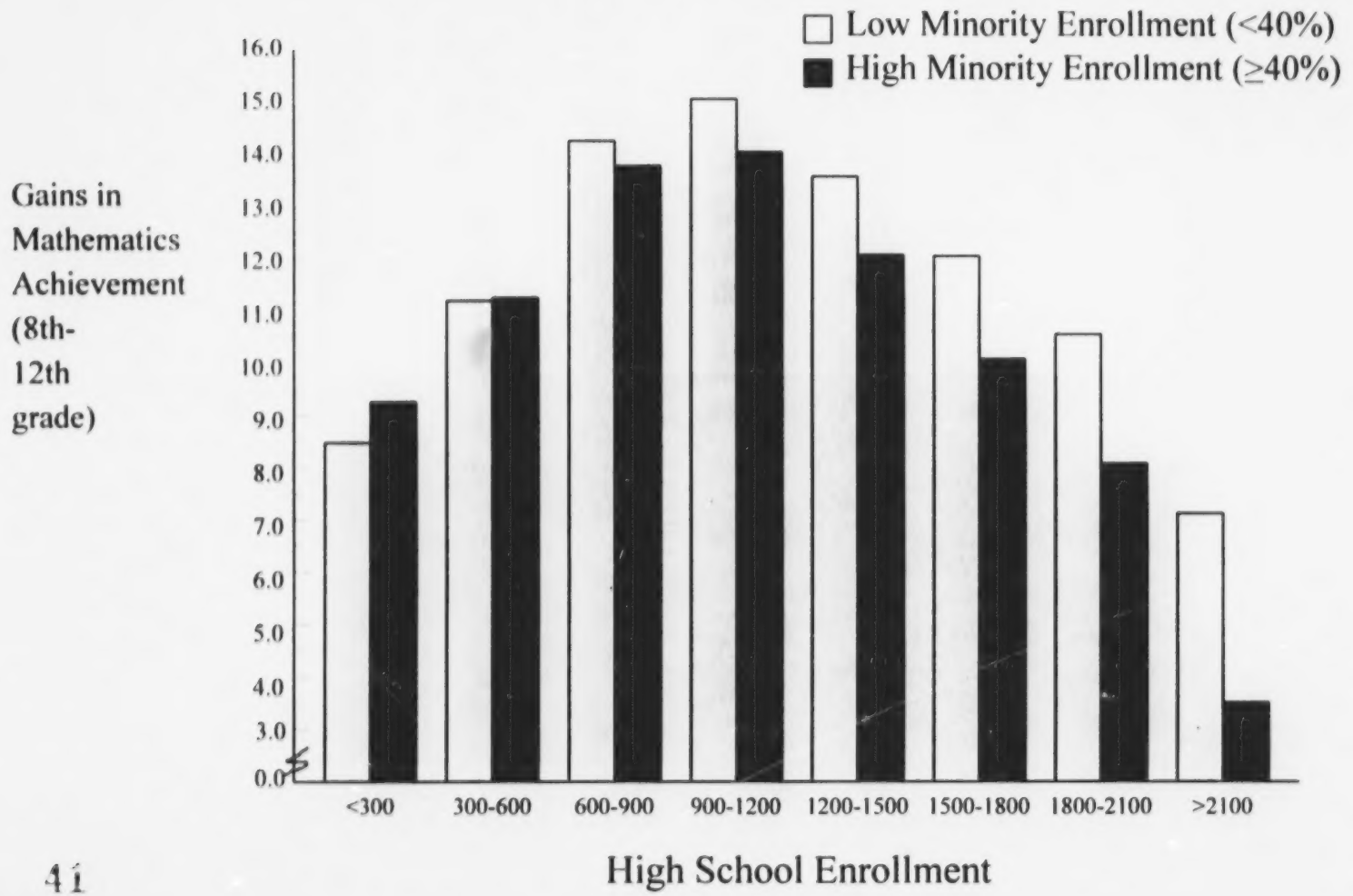
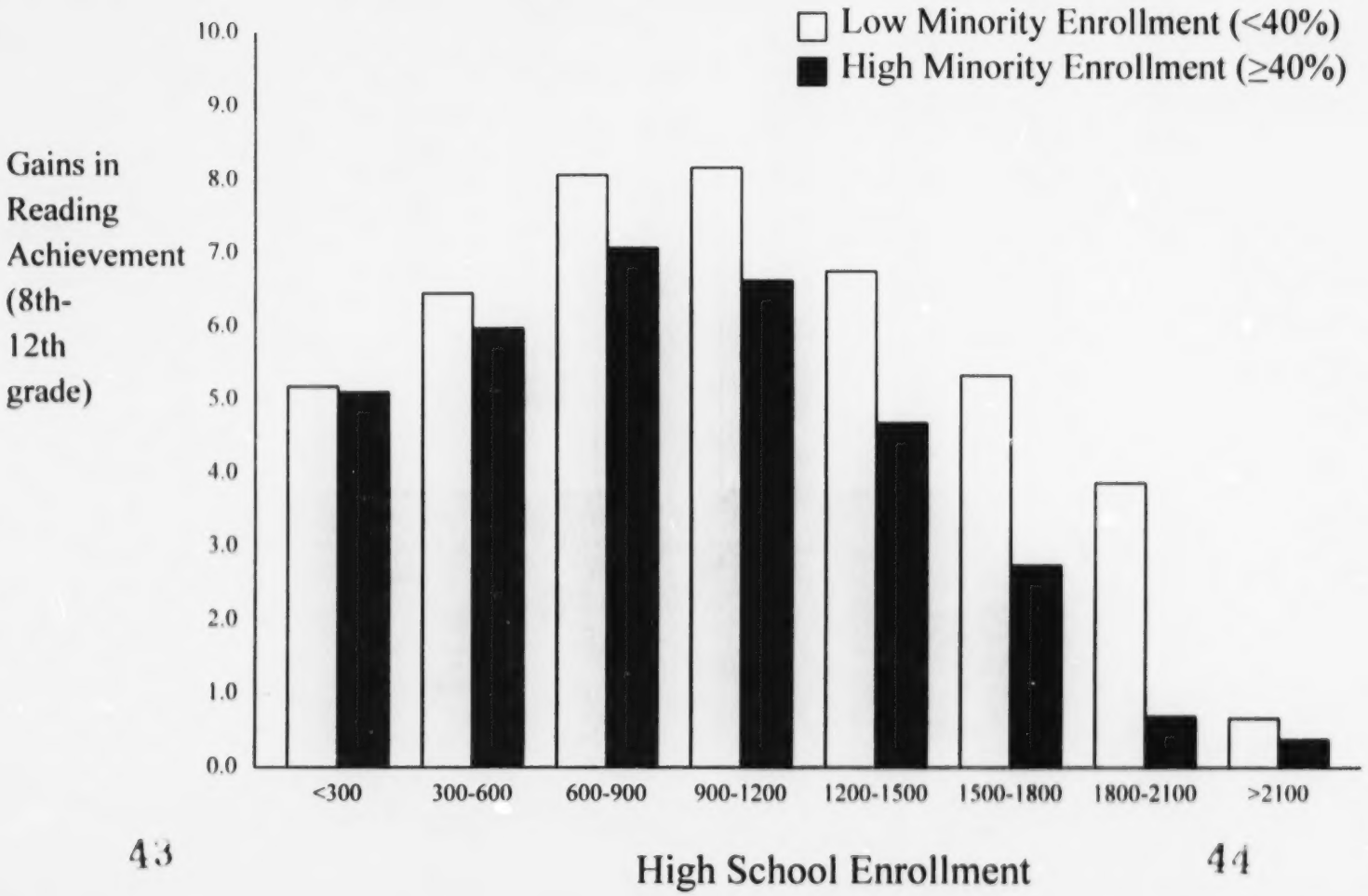


Figure 6: Average Gains in Reading Achievement by School Size in High Schools with Low- and High-Minority Enrollments



Appendix A: Description of Variable Construction for all Measures Used in The Study of School Size and Learning

Dependent Measures

o *Achievement Gains*

Mathematics gain between 8th and 12th grades was constructed as a simple difference in scores between:

+ BY2XMIRR -- Mathematics IRT-estimated number right (8th grade).
+ F22XMIRR -- Mathematics IRT-estimated number right (12th grade).

Reading gain between 8th and 12th grades was constructed as a simple difference in scores between:

+ BY2XRIRR -- Reading IRT-estimated number right (8th grade).
+ F22XRIRR -- Reading IRT-estimated number right (12th grade).

School Size

o *School Size*

+ F1C2 TOTAL ENROLLMENT AS OF OCTOBER 1989
  Principal's report of high school size (on NELS restricted school file).

+ School size categories (300 and below, 301-600, 601-900; 901-1200, 1201-1500, 1501-1800, 1801-2100, over 2100) were constructed from F1C2.

+ Two piecewise size terms were computed from the 8 size categories, using 900 as a base. The first linear term, for small schools, was coded -648.65, -444.59, -149.80, 0, 0, 0, 0, 0. The values here are the average sizes for each category, minus 900. The second term, for large schools, was coded 0, 0, 0, 152.32, 448.87, 748.72, 1048.81, 1737.27. Substantive information about this decision is in Note 4.

Control Variables

Student Background (within-school controls):

o *Socioeconomic Status*

+ F2SES1 -- socio-economic status z-scored composite.

o *Minority Status*

+ F2RACE1 -- student race (recoded to: 0=white or Asian; 1=black, Hispanic, or Native American).

o *Gender*

+ F2SEX Student gender (recoded to: 0=male; 1=female).

o *Academic Controls*

Analyses included different controls for the two curriculum areas. Controls were constructed as follows:

+ For math gain: Z-score of sum of BYTXRIRS, BYTXHIRS, BYTXSIRS.
+ For reading gain: Z-score of sum of BYTXMIRS, BYTXHIRS, BYTXSIRS.
+ BYS77 HOW OFTEN COME TO CLASS LATE (REVERSED)

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School Demographics and Structure (between school controls):

o *Average Socioeconomic Status*
  + AVSES -- SES composite, aggregated to the school level.

o *Minority Concentration*
  + F1RACE -- student race (recoded to: 0=white or Asian; 1=Black, Hispanic, or Native American), aggregated to the school level, and recoded to: 1=40% or more, 0=less than 40% minority.

o *Sector*
  Created from G10CTRL2, the school control measure on the NELS first followup restricted school file. Public, Catholic, and NAIS schools were retained, other private schools were dropped. Created 2 dummy-coded variables:
  + CATHOLIC -- coded 1 for Catholic, 0 for public, NAIS schools.
  + NAIS -- coded 1 for NAIS, 0 for public, Catholic schools.

Appendix B-1: **Average Gains in Reading and Mathematics, Weighted and Unweighted, by School Enrollment Category**

	Gains in Mathematics		Gains in Reading	
	Unweighted	Weighted	Unweighted	Weighted
Size Category	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
300 or less	-.87 (.38)	-.66 (.28)	-.34 (.83)	-.26 (.74)
301-600	-.09 (.24)	-.16 (.18)	.07 (.80)	.05 (.78)
601-900	1.37 (.63)	1.38 (.56)	.52 (.94)	.49 (.86)
901-1200	.61 (.16)	.68 (.16)	.48 (.88)	.44 (.86)
1201-1500	.07 (.19)	.10 (.16)	.14 (.99)	.19 (.88)
1501-1800	-.16 (.28)	-.09 (.24)	-.08 (.96)	.06 (.96)
1801-2100	-.50 (.22)	-.58 (.19)	-.46 (.81)	-.45 (.76)
2100 or more	-1.57 (.67)	-1.59 (.56)	-.77 (.92)	-.89 (.88)

Appendix B-2: **HLM Between-School Model for Investigating the Effects of School Size on Gains in Mathematics and Reading** (N=9,912 students in 789 Schools) (a)

	Dependent Variables	
	Gain in Mathematics Achievement, Gr.8-12	Gain in Reading Achievement, Gr.8-12
Effects on Average Between-School Achievement Gains (Intercept)		
Base Estimate (b)	12.847***	5.813***
Average SES (c)	.408***	.262**
Hi-Minority Enrl.	.217***	-.013
Catholic School	.790	-.093
NAIS School	-.023	-.365
School Size:(d)		
300 or less	-.931***	-.532*
301-600	-.089	.149
601-900	1.512***	.539*
901-1200	.589***	.290
1501-1800	-.152~	-.254
1801-2100	-.415**	-.455*
Over 2100	-1.842***	-.911***
Effects on Relationship Between SES and Gains (Slope)		
Base Estimate (b)	1.656***	1.387***
Average SES (c)	.342~	-.720
Hi-Minority Enrl.	-.361	-.043
Catholic School	-.213	-1.092
NAIS School	-.161	-1.382
School Size:(c)		
300 or less	-1.187~	-2.161
301-600	-.985***	-3.153*
601-900	-.667~	-2.156*
901-1200	-.123	-.487
1501-1800	.984**	2.115*
1801-2100	1.481***	3.795**
Over 2100	1.264**	3.876**
HLM-computed SD		
Intercept	2.276	1.494
SES/Gain Slope	0.950	0.347

~ $p \leq .10$; * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

a. These HLM effects are estimated using the constructed school-level weight, as described in the text and Note 1.

b. HLM results computed with within-school adjustments for SES, minority status, gender, and 8th-grade ability.

c. All effects (except the average values on the intercept and SES/gain slopes) are presented are in a standardized effect-size metric. Effects computed by dividing the HLM gamma coefficient for each outcome by the school-level standard deviation (SD) for that outcome computed from the Level 1 HLM models. These SDs are in the bottom panel of this table.

d. All school-size effects are compared to schools that enroll 1200-1500 students, which is the excluded category.

Appendix B-3: **Unweighted HLM Estimates of School Size Effects on Gains in Mathematics and Reading** (N=9,912 students in 789 Schools) (a)

	Dependent Variables	
	Gain in Mathematics Achievement, Gr.8-12	Gain in Reading Achievement, Gr.8-12
Effects on Average Between-School Achievement Gains (Intercept) (b)		
School Size: (c)		
300 or less	-.292*	.417~
301-600	-.469	.038
601-900	.473***	.630***
901-1200	.347*	.588***
1501-1800	-.130	.012
1801-2100	-.341*	-.320*
Over 2100	-.574*	-.564**
Effects on Relationship Between SES and Gains (Slope) (b)		
School Size: (c)		
300 or less	-1.220*	-1.113
301-600	-.571	-1.666
601-900	-.651~	-.967
901-1200	-.602~	-1.382
1501-1800	.571~	.005
1801-2100	.736*	1.937~
Over 2100	.786*	2.859**
HLM-computed SD		
Intercept	1.494	1.451
SES/Gain Slope	0.347	0.398

~ $p \leq .10$; * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

a. The HLM models include all variables described in the HLM models described elsewhere in this paper (Level 1: SES, gender, race/ethnicity, and 8th-grade ability; Level 2: average school SES, minority concentration, Catholic, and NAIS sector).

b. As in Appendix B-2, all size effects are presented are in a standardized effect-size metric. Effects computed by dividing the HLM gamma coefficient for each outcome by the school-level standard deviation (SD) for that outcome shown in the bottom panel of this table. Note that these are are somewhat smaller than those computed in weighted HLM runs (Appendix B-2).

c. All school-size effects are compared to schools that enroll 1200-1500 students, which is the excluded category.

Appendix B-4: **HLM Between-School Model Investigating School Size-by-Average SES Interactions on Gains in Mathematics** (N=9,912 students in 789 Schools) (a)

	Gain in Mathematics Achievement, Gr.8-12
Effects on Average Between-School Mathematics Gains (Intercept)	
Base Estimate (b)	10.733***
Average SES (c)	0.593*
Hi-Minority Enrl.	0.653**
Catholic School	-1.793***
NAIS School	-0.100
School Size Main Effects (Effects-Coded): (d)	
300 or less	-0.740***
301-600	-0.075
601-900	0.889***
901-1200	0.334**
1501-1800	-0.171
1801-2100	-0.277~
Over 2100	-1.117
School Size-by-Average SES Interaction Terms: (d)	
< 300 X AVSES	-0.089
301-600 X AVSES	-0.496**
601-900 X AVSES	-0.541**
901-1200 X AVSES	-0.446*
1501-1800 X AVSES	-0.056
1801-2100 X AVSES	0.119
> 2100 X AVSES	0.144

~ $p \leq .10$; * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$

a. These HLM effects are estimated using the constructed school-level weight, as described in the text and Note 1. Although this analysis also included estimates on the SES/gain slope, and interaction terms on that outcome, those results are not presented here. There were no significant interactions effects on the SES/gain slope.

b. HLM results computed with within-school adjustments for SES, minority status, gender, and 8th-grade ability.

c. All effects are presented as unadjusted gamma coefficients from HLM, rather than as effect sizes. As described in Note 10, In order to consider balanced interaction terms, the school size categories were recoded in an effects-coded metric (1, -1), rather than the dummy coding (1,0) in the other analyses in this paper. The set of interaction terms were created as products between average school SES and each effect-coded school size indicator. The average math gains shown in Figure 4 were computed by summing these main effects and interaction terms for each size category, separ- ately in lower-SES (1 SD below the mean) and higher-SES schools (1 SD above the mean), as explained in the text.

d. All school-size effects are compared to schools that enroll 1200-1500 students, which is the excluded category.

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